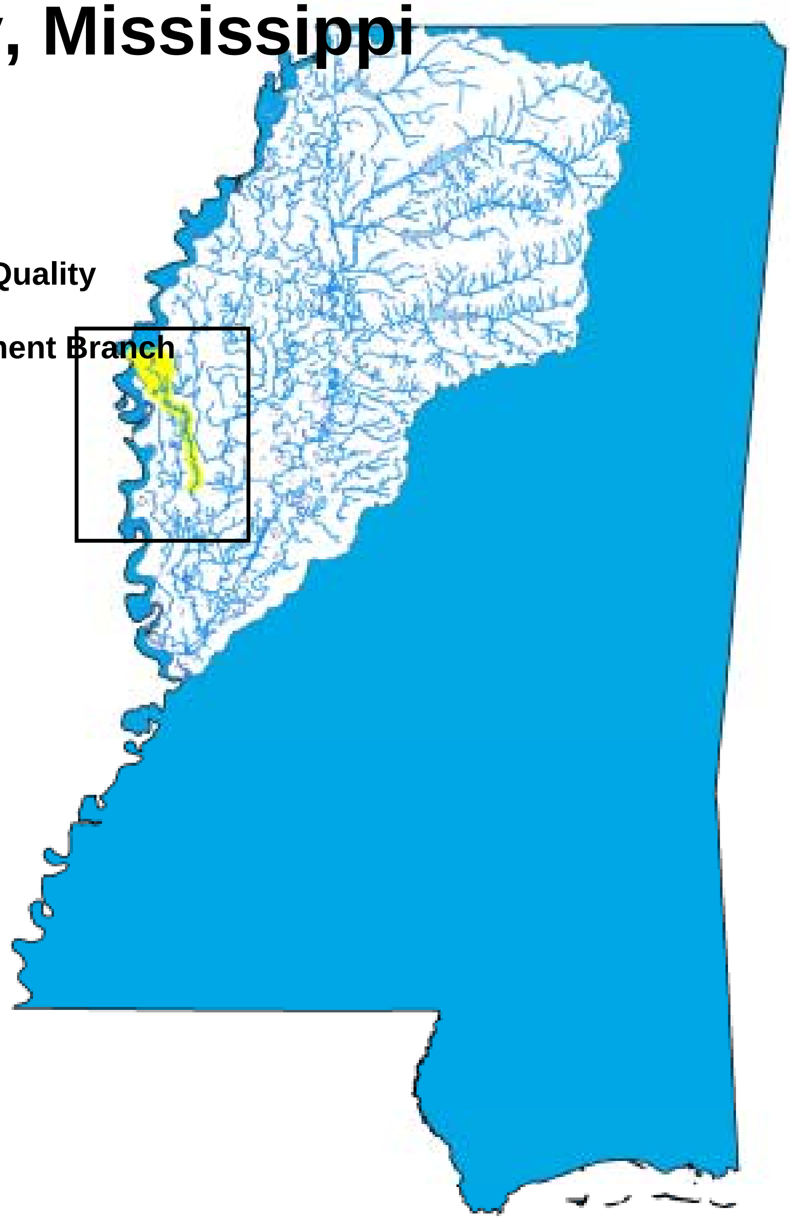
FINAL REPORT
June 2003

Phase 1
Total Maximum Daily Load
For Organic Enrichment/Low DO and Nutrients

Deer Creek
Yazoo River Basin

Washington County, Mississippi



Prepared By

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FOREWORD

This report has been prepared in accordance with the schedule contained within the federal consent decree dated December 22, 1998. The report contains one or more Total Maximum Daily Loads (TMDLs) for waterbody segments found on Mississippi's 1996 Section 303(d) List of Impaired Waterbodies. Because of the accelerated schedule required by the consent decree, many of these TMDLs have been prepared out of sequence with the State's rotating basin approach. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

The amount and quality of the data on which this report is based are limited. As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, or changes in landuse within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

Prefixes for fractions and multiples of SI units

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deka	da
10^{-2}	centi	c	10^{2}	hecto	h
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	μ	10^{6}	mega	M
10^{-9}	nano	n	10^{9}	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

Conversion Factors

To convert from	To	Multiply by	To Convert from	To	Multiply by
Acres	Sq. miles	0.0015625	Days	Seconds	86400
Cubic feet	Cu. Meter	0.028316847	Feet	Meters	0.3048
Cubic feet	Gallons	7.4805195	Gallons	Cu feet	0.133680555
Cubic feet	Liters	28.316847	Hectares	Acres	2.4710538
cfs	Gal/min	448.83117	Miles	Meters	1609.344
cfs	MGD	.6463168	mg/l	ppm	1
Cubic meters	Gallons	264.17205	μg/l * cfs	Gm/day	2.45

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PHOTOS

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TMDL INFORMATION PAGE

i. Listing Information

Name	ID	County	HUC	Cause	Mon/Eval
Deer Creek segment 6	MS403M6	Washington	08030209	Organic Enrichment/Low DO	Monitored
Near Hollandale: From Arcola to Percy					
Deer Creek segment 6	MS403M6	Washington	08030209	Nutrients	Monitored
Near Hollandale: From Arcola to Percy					
Deer Creek – DA	MS402E	Bolivar	08030209	Organic Enrichment/Low DO and Nutrients	Evaluated
Drainage Area near Winterville					
Deer Creek – DA	MS402E	Bolivar	08030209	Nutrients	Evaluated
Drainage Area near Winterville					

ii. Water Quality Standard

Parameter	Beneficial use	Water Quality Criteria
Dissolved Oxygen	Aquatic Life Support	DO concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l

iii. NPDES Facilities

NPDES ID	Facility Name	Permitted Discharge (MGD)	Receiving Water
MS0040339	J. Whitten Delta Research	0.05	Deer Creek
MS0047791	National Warm Water Aquaculture Center	0.576	Deer Creek

iv. Total Maximum Daily Load for TBODu

LA (lbs/day)	WLA (lbs/day)	MOS	TMDL (lbs/day TBODu)
84.0	81.8	Implicit	165.8

EXECUTIVE SUMMARY

A segment of the Deer Creek has been placed on the Mississippi 1998 Section 303(d) List of Waterbodies as a monitored waterbody segment, due to organic enrichment/low dissolved oxygen and nutrients. In addition, a drainage area in the upper part of the watershed has been listed as an evaluated area due to organic enrichment/low DO and nutrients. The applicable state standard specifies that the DO concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l. Mississippi currently does not have standards for allowable nutrient concentrations, so a TMDL specifically for nutrients will not be developed. However, because elevated levels of nutrients may cause low levels of dissolved oxygen, the TMDL developed for dissolved oxygen also addresses the potential impact of elevated nutrients in Deer Creek.

Deer Creek is located in the Mississippi River alluvial plane and flows in a southern direction from Lake Bolivar near Scott, Mississippi to the Yazoo River. The 303(d) listed segment flows from near Arcola to Percy, Mississippi in Washington County. Photo 1 shows Deer Creek near Hollandale, which is within the 303(d) Listed segment. Much of the flow that was in Deer Creek has been diverted into Rolling Fork Creek at Rolling Fork, Mississippi, which is downstream of the 303(d) listed segment.

Photo 1. Deer Creek near Hollandale

The predictive model used to calculate this Phase 1 TMDL is based primarily on assumptions described in MDEQ Regulations. A modified Streeter-Phelps DO sag model was selected as the modeling framework for performing the TMDL allocations for this study. The model was developed to account for critical conditions in stream temperature, dissolved oxygen saturation, and carbonaceous biochemical oxygen demand (CBODu) decay rate. A mass-balance approach was used to ensure that the instream concentration of ammonia nitrogen (NH_3-N) did not exceed the water quality criteria for toxicity. The critical modeling period was determined to be during low-flow, high-temperature conditions that occur during the summer (May – October) period. This flow condition is typically represented as the 7-day, 10-year low flow (7Q10 flow). However, because streams located in the Mississippi River alluvial plain are known to have a decreasing flow trend with time, 7Q10 flows are not available for streams in this area. Because of this, a low-flow coefficient was developed for this watershed based on flow data from the nearby Bogue Phalia watershed. The low-flow coefficient was then applied to the Deer Creek watershed to estimate the low-flow condition for this watershed.

The model used in developing this Phase 1 TMDL included both nonpoint and point sources of total ultimate biochemical oxygen demand (TBODu) in the Deer Creek Watershed. This TMDL has been developed as a Phase 1 TMDL because data collected during the critical conditions, that could be used to calibrate the model, are not currently available. The location of the watershed is shown in Figure 1. TBODu loading from nonpoint sources in the watershed was accounted for by using an estimated background concentration of TBODu in the stream. In addition, the estimated organic loading from direct discharges of wastewater into Deer Creek was included as an additional nonpoint source. There are two NPDES Permitted discharges located in the watershed that are included as point sources in the model. The load and waste load allocations developed for TBODu are equal to the maximum assimilative capacity of Deer Creek, as indicated by predictive modeling. Thus, there is no assimilative capacity for additional TBODu loading in this waterbody segment.

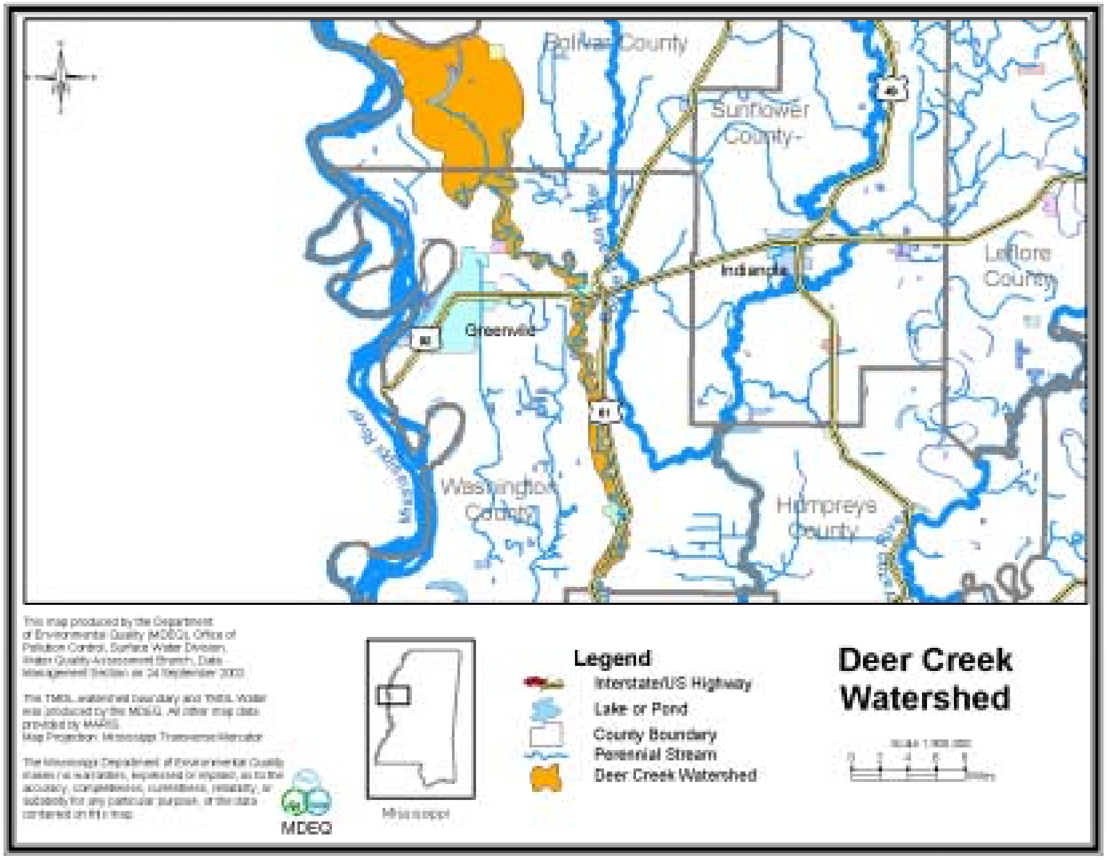


Figure 1. Deer Creek Watershed

INTRODUCTION

1.1 Background

The identification of waterbodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those waterbodies are required by Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The TMDL process is designed to restore and maintain the quality of those impaired waterbodies through the establishment of pollutant specific allowable loads. The impairment is caused by reduced levels of dissolved oxygen (DO) in the creek due to enrichment of the creek with nutrients and oxidation of organic material. Thus, this TMDL has been developed for organic enrichment. This TMDL was developed for the 303(d) listed segment and watershed shown in Figure 2.

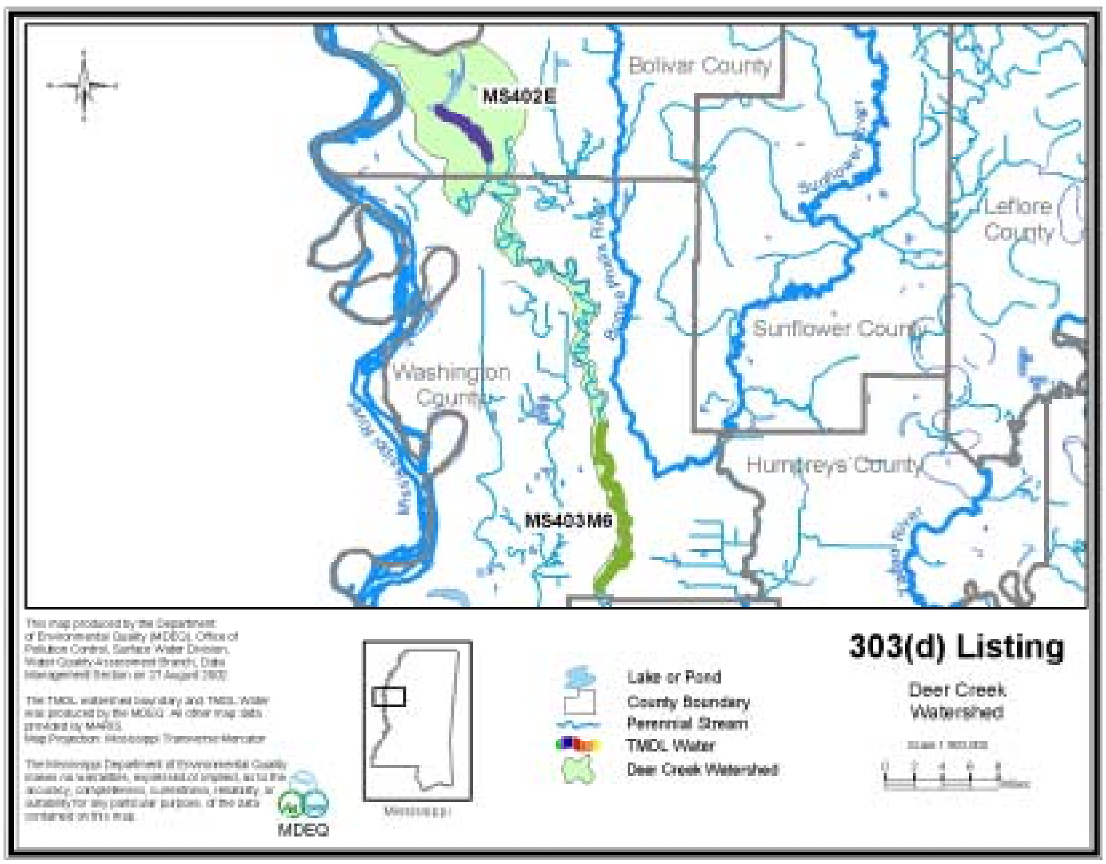


Figure 2. Deer Creek Watershed 303(d) Listed Segment and Drainage Area

Organic enrichment is measured in terms of total ultimate biochemical oxygen demand (TBODu). TBODu represents the oxygen consumed by microorganisms while stabilizing or degrading carbonaceous and nitrogenous compounds under aerobic conditions over an extended time period. The carbonaceous compounds are referred to as CBODu, and the nitrogenous compounds are referred to as NBODu. TBODu is equal to the sum of NBODu and CBODu, Equation 1.

$$TBODu = CBODu + NBODu \qquad \textbf{(Equation 1)}$$

1.2 Applicable Waterbody Segment Use

The water use classification for the listed segment of Deer Creek, as established by the State of Mississippi in the *Water Quality Criteria for Intrastate, Interstate and Coastal Waters* regulation, is Fish and Wildlife Support. The designated beneficial uses for Deer Creek are Secondary Contact and Aquatic Life Support.

1.3 Applicable Waterbody Segment Standard

The water quality standard applicable to the use of the waterbody and the pollutant of concern is defined in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. The applicable standard specifies that the dissolved oxygen (DO) concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l. The 5.0 mg/l water quality standard will be used as targeted endpoints to evaluate and establish this TMDL.

1.4 Selection of a TMDL Endpoint and Critical Condition

One of the major components of a TMDL is the establishment of instream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints, therefore, represent the water quality goals that are to be achieved by meeting the load and wasteload allocations specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses. The instream DO target for this TMDL is a daily average of not less than 5.0 mg/l. The instantaneous minimum portion of the DO standard was considered when establishing the instream target for this TMDL. However, it was determined that using the daily average standard with the conservative modeling assumptions would be protect the instantaneous minimum standard.

Low DO typically occurs during seasonal low-flow periods of late summer and early fall. Elevated oxygen demand is of primary concern during low-flow periods because the effects of minimum dilution and high temperatures combine to produce the worst-case potential effect on water quality (USEPA, 1997). The low-flow, high-temperature period is referred to as the critical condition. The maximum impact of oxidation of organic material is generally not at the location of the point source discharge, but at some distance downstream, where the maximum DO deficit occurs. The DO deficit is defined as the difference between the DO concentration at 100% saturation and the actual DO. The endpoint for this TMDL will be based on a daily average of not less than 5.0 mg/l DO within the 303(d) listed segment during critical conditions in Deer Creek.

WATERBODY ASSESSMENT

This TMDL Report includes an analysis of available water quality data and the identification of all known potential pollutant sources in the Deer Creek watershed. The potential point and nonpoint pollutant sources were characterized by the best available information, monitoring data, and literature values. This section documents the available information for Deer Creek.

2.1 Discussion of Instream Water Quality Data

The State's 1998 Section 305(b) Water Quality Assessment Report was reviewed to assess water quality conditions and data available for the watershed. Limited water quality data are available for the listed segments of Deer Creek. According to the report, Deer Creek is not supporting for the use of aquatic life support. These conclusions were based on instantaneous water chemistry data and screening-level biological assessment conducted at station 07288770. This monitoring station was part of MDEQ's basin assessment monitoring program. This station is located near Hollandale. The data from this station are given in Table 1 and Table 2. Data collected by the United States Geological Survey (USGS) at station 07288770 are given in Table 3 and Table 4. Additional water quality samples have been collected on Deer Creek by the Natural Resource Conservation Service (NRCS). Water quality data were collected at several locations on Deer Creek; Leland, Hollandale, Rolling Fork, Cary, Onward, and Valley Park, between 1993 and 1997 by NRCS. These data have been published in the *Mississippi Delta Comprehensive, Multipurpose, Water Resources Plan* (NRCS, 1988). Parameters sampled included depth, DO, pH, temperature, conductivity, total dissolved solids, turbidity, total Kjeldahl nitrogen, nitrate, total phosphorous, orthophosphorous, total suspended solids, and alkalinity. Samples for these parameters were collected on a monthly basis. Summaries of the data collected at two of the stations, Leland and Hollandale, which are just upstream and within the 303(d) listed segment are given in Tables 5 through 8. The NRCS data from Leland were collected between October 1993 and October 1997. The NRCS data from Hollandale were collected between October 1993 and September 1995. The data given in Tables 5 through 8 are provisional at this time because the procedures used to collect the data have not been reviewed by MDEQ.

Additional water quality sampling has been recently conducted as part of an ongoing restoration effort in Deer Creek. The restoration effort includes several state and federal agencies; USGS, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Yazoo-Mississippi-Delta Joint Water Management District, and MDEQ. The restoration efforts may include repairing failing septic systems, cleaning up illegal trash dumps, improving landscapes to minimize nonpoint source pollution, and possibly augmenting flow to reestablish the natural flow patterns in the lower part of the watershed. The recent sampling efforts were intended to characterize baseline conditions in the watershed prior to beginning restoration efforts. The sampling effort included six sites along Deer Creek; below Lake Bolivar (at Scott, MS), Leland, Hollandale, Rolling Fork, Cary, and Valley Park. Samples were collected for several parameters including temperature, DO, pH, conductivity, organic carbon, 5-day BOD, chlorophyll-a, nutrients, and pesticides in September of 2002. Sampling for all of these parameters will continue on a monthly basis for the sampling sites at Leland and Cary. The study also included collection of benthic macroinvertebrates at each station. Selected provisional data from this study are given in Tables 9 and 10. It is important to note that the monitoring stations at Rolling Fork, Cary, and Valley

Park are located downstream from the segment of Deer Creek included on the 303(d) List and the TMDL model.

Table 1. Water Quality Data for Deer Creek, MDEQ Station 07288770

Sample Date	Sample Time	Temperature (°C)	Specific Conductivity (μmhos/cm)	Dissolved Oxygen (mg/L)	pH
5-Jan-88	11:20	7	50	8	6.75
8-Mar-88	9:50	14	120	-	6.96
2-May-88	10:46	20	170	3.1	6.34
5-Jul-88	11:30	27	722	0.3	6.99
6-Sep-88	11:20	23	900	0.9	7.14
7-Nov-88	12:10	14	460	3.5	7.67
10-Jan-89	9:30	8.5	70	7.8	6.37
1-May-89	9:05	20	185	2.1	6.67
11-Jul-89	12:00	26	130	2.5	6.38
5-Sep-89	6:20	27	60	1.6	7.37
7-Nov-89	9:00	15	138	6.0	9.03
8-Jan-90	11:10	8	60	10.2	6.77
5-Mar-90	9:05	14.5	140	13.3	7.05
1-May-90	6:20	34	200	6.8	7.7
9-Jul-90	8:30	27	60	3.2	6.8
4-Sep-90	9:00	15	500	1.2	6.7
7-Nov-90	11:15	7	50	3.3	7.86

Table 2. Water Quality Data for Deer Creek, Station 07288770, Continued

Sample Date	Sample Time	TKN (mg/L)	Nitrite + Nitrate (mg/L)	Total Phosphorous (mg/L)	COD (mg/L)	TSS (mg/L)
5-Jan-88	11:20	0.90	0.46	0.22	14	59
8-Mar-88	9:50	1.16	1.18	0.31	19	156
2-May-88	10:46	1.00	0.50	0.38	28	45
5-Jul-88	11:30	2.10	0.21	3.60	35	35
6-Sep-88	11:20	2.10	0.07	2.60	50	36
7-Nov-88	12:10	2.60	0.29	1.23	64	26
10-Jan-89	9:30	1.20	0.68	0.43	30	47
1-May-89	9:05	2.70	0.98	0.68	205	226
11-Jul-89	12:00	0.63	0.19	0.45	6	27
5-Sep-89	6:20	1.35	0.23	0.45	7	4
7-Nov-89	9:00	1.87	0.85	0.25	41	75
8-Jan-90	11:10	1.56	0.46	0.30	6	60
5-Mar-90	9:05	1.80	0.69	0.40	16	126
1-May-90	6:20	0.31	0.51	0.34	1	26
9-Jul-90	8:30	2.48	0.06	0.46	22	40
4-Sep-90	9:00	4.87	0.07	1.43	44	16
7-Nov-90	11:15	1.61	0.64	2.46	20	18

Table 3. Water Quality Data for Deer Creek, Station 07288770, Continued

Sample Date	Sample Time	Temperature (°C)	Specific Conductivity (μmhos/cm)	Dissolved Oxygen (mg/L)	pH
4/12/1995	14:55	20.1	137	5.9	5.9
4/19/1995	12:40	22.3	182	5.6	5.6
5/3/1995	13:20	8.3	98	6.3	6.3
5/16/1995	-	28.7	141	4.5	4.5
5/30/1995	14:30	24.2	178	1.6	1.6
6/13/1995	13:35	26.7	222	5.9	5.9
6/27/1995	14:20	27.9	213	4.5	4.5
7/5/1995	12:52	25.3	217	2.6	2.6
7/12/1995	15:10	29.7	173	4.6	4.6
7/18/1995	14:10	31	157	4.2	4.2
7/25/1995	13:30	30.5	176	5	5
8/1/1995	13:45	28.9	234	3.1	3.1
8/8/1995	17:00	31.4	188	5.2	5.2
8/14/1995	12:00	29.5	208	3.3	3.3
8/23/1995	11:30	29.4	243	4	4
8/29/1995	12:25	28.8	341	2.8	2.8
9/12/1995	12:00	24.1	482	6.8	6.8
9/26/1995	13:05	21.2	660	2.8	2.8
10/12/1995	12:22	-	482	-	-
10/12/1995	12:30	19.5	807	6.8	6.8
11/1/1995	11:00	15.9	817	8.5	8.5
1/23/1996	12:35	8	301	4.2	4.2
2/29/1996	11:15	12.1	271	5.3	5.3
3/12/1996	11:45	8.1	319	4.6	4.6
4/10/1996	13:25	11	262	9.3	9.3
5/21/1996	12:30	26.4	174	12.1	12.1
7/17/1996	14:00	29	403	1.4	1.4
8/13/1996	15:10	28	260	3.1	3.1
5/6/1997	18:45	20.6	114	5.2	5.2
7/11/1997	10:30	29.5	192	3	3
8/1/1997	9:20	28.7	218	4.2	4.2
8/1/1997	9:20	28.5	218	4.2	4.2
9/9/1997	13:00	26	303	4.7	4.7
6/18/1998	8:00	29.5	154	3	3

Table 4. Water Quality Data for Deer Creek, Station 07288770, Continued

Sample Date	Sample Time	TKN Total (mg/L)	TKN Dissolved (mg/L)	Nitrite + Nitrate (mg/L)	NH_3-N (mg/L)	Total P (mg/L)	Dissolved P (mg/L)	Dissolved Ortho P (mg/L)
5/6/1997	18:45	1.0	0.58	2.51	0.17	0.31	0.15	0.13
7/11/1997	10:30	1.1	0.56	0.57	0.16	0.24	0.08	0.08
9/9/1997	13:00	1.5	1.00	0.39	0.50	0.19	0.09	0.07
5/6/1997	18:45	1.0	0.58	2.51	0.17	0.31	0.15	0.13

Table 5. Summary of NRCS Data Collected in Leland, SE Deer Creek Drive

	Depth (ft)	DO (mg/L)	pH	Conductivity (μmhos/cm)	TDS (mg/L)	Turbidity (NTU)	Temperature (°C)
Number of Samples	41	47	47	47	47	47	47
Average	13.86	7.0	7.34	267.5	133.9	204.8	19.4
Maximum	15.70	12.6	8.30	633.0	317.0	1911.0	35.0
Minimum	9.10	3.0	6.40	77.0	40.0	14.0	6.8

Table 6. Summary of NRCS Data Collected in Leland, SE Deer Creek Drive, Continued

	TKN (mg/L)	Nitrate (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Total Solids (mg/L)	TSS (mg/L)	Alkalinity (mg/L)
Number of Samples	47	47	47	47	47	47	47
Average	1.4	0.5	0.37	0.13	316.2	97.4	110.15
Maximum	3.5	5.9	0.96	0.37	1130.0	1051.0	305.00
Minimum	0.7	0.0	0.11	0.01	162.0	2.0	17.00

Table 7. Summary of NRCS Data Collected in Hollandale, Murphy Road

	Depth (ft)	DO (mg/L)	pH	Conductivity (μmhos/cm)	TDS (mg/L)	Turbidity (NTU)	Temperature (°C)
Number of Samples	12	18	18	18	18	18	18
Average	17.6	5.31	7.27	226.50	113.83	102.59	21.49
Maximum	20.8	8.60	7.83	552.00	277.00	557.00	30.00
Minimum	12.8	2.40	6.76	97.00	48.00	5.00	8.40

Table 8. Summary of NRCS Data Collected in Hollandale, Murphy Road, Continued

	TKN (mg/L)	Nitrate (mg/L)	Total P (mg/L)	Ortho P (mg/L)	Total Solids (mg/L)	TSS (mg/L)	Alkalinity (mg/L)
Number of Samples	18	18	18	18	18	18	18
Average	1.28	0.26	0.43	0.23	239.17	82.28	94.11
Maximum	2.80	1.11	1.25	1.00	515.00	467.00	247.00
Minimum	0.64	0.00	0.13	0.05	108.00	0.00	22.00

Table 9. Water Quality Data Collected for Deer Creek Restoration Project

Station	Sample Date	Sample Time	Temperature (°C)	Specific Conductivity (μmhos/cm)	Dissolved Oxygen (mg/L)	pH
AT SCOTT	Aug 28 2002	1338	29.5	159	5.3	7.3
AT SCOTT	Sep 5 2002	1730	31.5	160	7.8	7.9
AT SCOTT	Sep 6 2002	1300	29.5	167	4.4	7.2
EAST OF LELAND	Sep 5 2002	1600	29.5	500	6.9	7.7
NEAR HOLLANDALE	Aug 28 2002	1230	27.5	165	3.5	7.1
NEAR HOLLANDALE	Sep 5 2002	1230	28.5	161	4.6	6.9
NEAR HOLLANDALE	Sep 6 2002	1108	28.0	163	4.9	7.2
AT ROLLING FORK	Aug 28 2002	1150	29.5	92	8.4	7.8
AT ROLLING FORK	Sep 5 2002	0945	29.5	214	4.9	7.2
AT ROLLING FORK	Sep 6 2002	1020	26.0	235	5.3	7.3
AT CARY	Aug 28 2002	1110	27.5	173	4.8	7.2
AT CARY	Sep 4 2002	1500	29.5	173	3.4	7.1
AT CARY	Sep 6 2002	0940	28.0	176	7.9	7.0
AT VALLEY PARK	Aug 28 2002	1015	26.5	103	0.4	6.5
AT VALLEY PARK	Sep 4 2002	0930	30.5	101	6.6	7.1
AT VALLEY PARK	Sep 4 2002	1030	26.5	105		6.2
AT VALLEY PARK	Sep 6 2002	0855	26.5	102	1.4	6.5

Table 10. Water Quality Data Collected for Deer Creek Restoration Project

Station	Sample Date	Sample Time	TKN Total (mg/L)	TKN Dissolved (mg/L)	Nitrite + Nitrate Total (mg/L)	NH_3-N (mg/L)	Total P (mg/L)	Dissolved Ortho P (mg/L)	BOD_5 (mg/L)
AT SCOTT	Sep 5 2002	1730	1.6	0.9	0.01	0.15	0.24	0.1	5.1
EAST OF LELAND	Sep 5 2002	1600	0.9	0.6	<0.01	0.02	0.12	0.07	3.7
NEAR HOLLANDALE	Sep 5 2002	1230	1	0.6	<0.01	0.02	0.22	0.07	2.7
AT ROLLING FORK	Sep 5 2002	0945	1.3	0.9	0.01	0.04	0.42	0.24	3.8
AT CARY	Sep 4 2002	1500	1.1	0.6	0.01	0.03	0.18	0.03	3.5
AT VALLEY PARK	Sep 4 2002	1030	3.9	0.7	<0.01	0.01	0.34	<0.01	4.7

The DO data given in Tables 1 and 3 were further analyzed to determine when excursions of the DO standard are most likely to occur. An analysis of this type will determine the environmental conditions and pollutant sources that have the largest impact on the water body. Because the DO data given in these tables are instantaneous measurements, they were compared to the instantaneous portion of the standard. Figure 3 shows a plot of the measured DO compared to the water temperature. The points on the figure represent all of the data that were collected at station 07288770. The line on the figure is at 4.0 mg/l DO, the instantaneous portion of the standard. As shown in the figure, the majority of the DO excursions occur during warmer periods, when water temperatures are greater than 20°C. Only three of the nineteen DO violations in Figure 3 occurred at temperatures below 20°C. The DO measurements were also compared to the month in which they were collected in order to look for seasonal trends, Figure 4. This figure shows that the majority of the DO excursions occur during the months of May through October. These months are considered to be the summer months in Mississippi, in which temperatures are elevated and lower flows are expected. Only two of the nineteen DO violations occurred outside of this period, in the month of November.

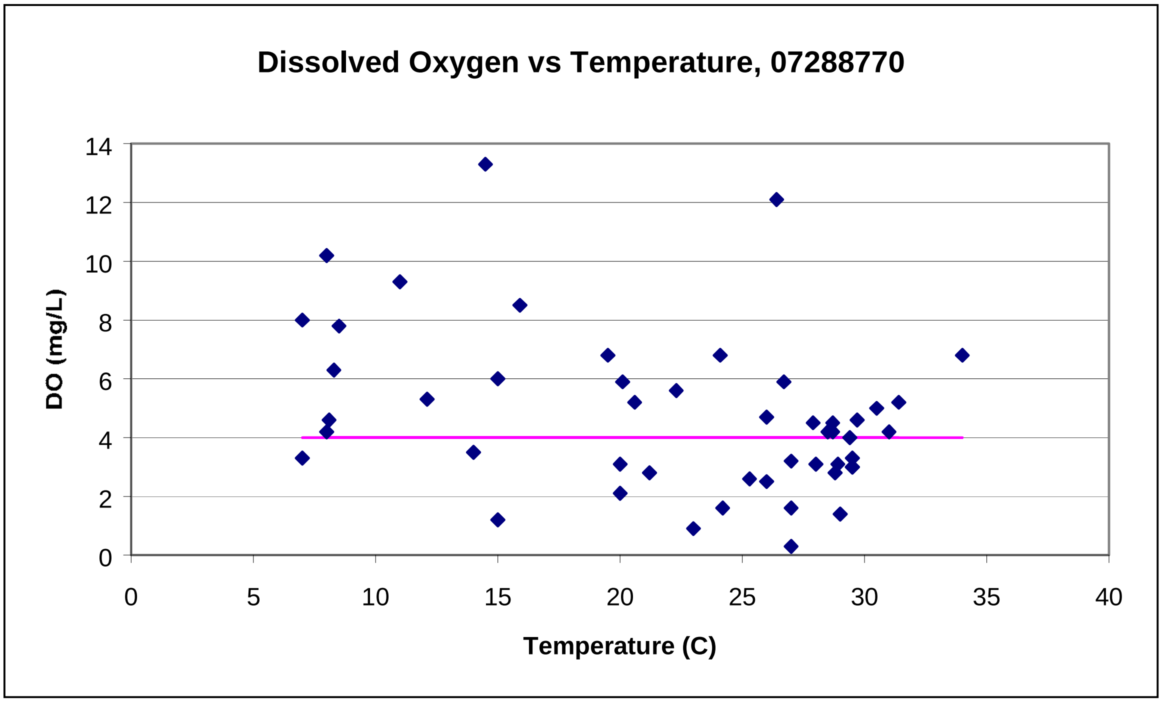


Figure 3. DO Data Compared to Temperature Data

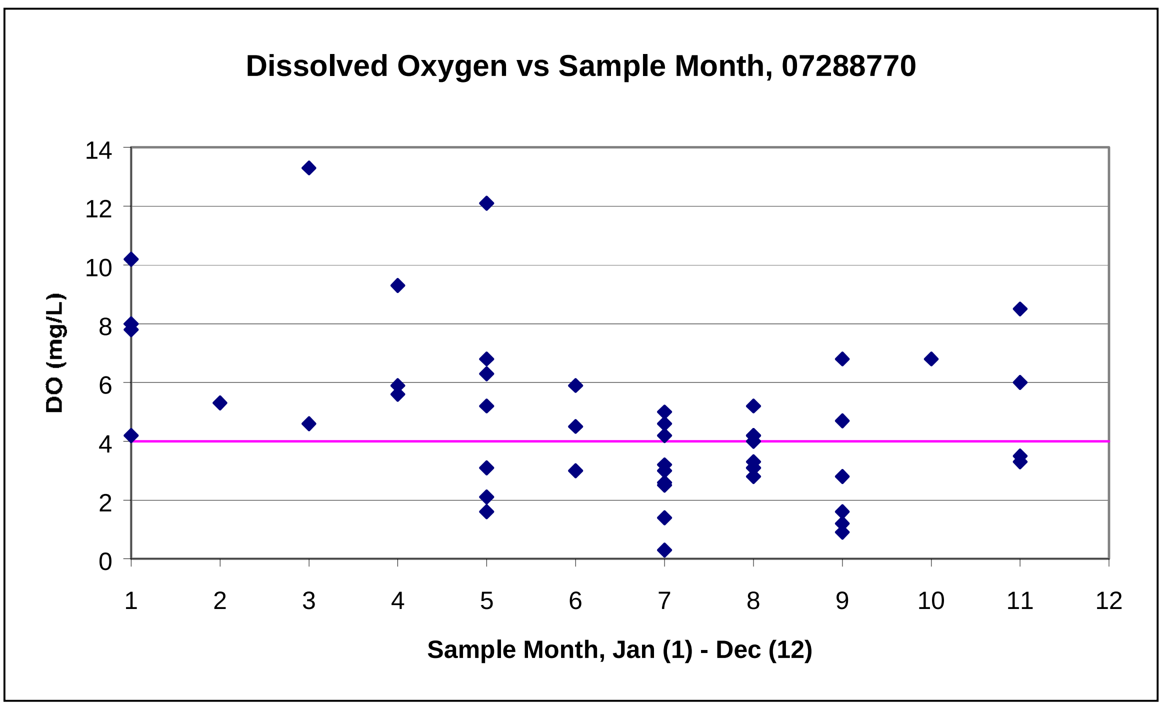


Figure 4. DO Data Compared to Sample Month

Examination of Figures 3 and 4 shows that the majority of the measured DO violations occurred during the higher temperature, lower flow periods. Sources of organic material, which could deplete DO levels during this time period, would include point source dischargers and other sources that occur on a continual basis such as discharges from failing septic systems. These sources would have their maximum impact during low-flow conditions, since dilution would be at a minimum. The DO violations measured during the cooler, winter period would likely be due to a combination of both continuous sources and intermittent sources such as pollutants carried to the water body during rainfall and runoff events. Due to the distribution of DO violations shown in the figures it is apparent that the continuous sources have the largest impact on water quality.

2.2 Assessment of Point Sources

The first step in assessing pollutant sources in the Deer Creek watershed was locating the NPDES permitted sources. There are two sources permitted to discharge into Deer Creek, Table 11. The effluent from each facility was characterized based on all available data including information on each facility's wastewater treatment system, permit limits, and discharge monitoring reports (DMRs). DMRs are vital to characterizing effluent from each facility. The average flows, BOD_5, and NH_3-N concentrations, as reported in DMRs for the past two years (8/1/2000 through 8/1/2002), are given in Table 11. The permit limits for both facilities allow a monthly average BOD_5 concentration of 10 mg/L and NH_3-N concentration of 2.0 mg/L.

Table 11. Identified NPDES Permitted Facilities

Name	NPDES Permit	Permitted Discharge (MGD)	Actual Average Discharge (MGD)	Actual BOD_5 (mg/L)	Actual NH_3-N (mg/L)
J. Whitten Delta Research	MS0040339	0.05	No Discharge		
National Warm Water Aquaculture Center	MS0047791	0.576	0.108	4.28	1.40

A third NPDES permit for the Hollandale POTW has expired, and the discharge was removed from the Deer Creek watershed in 2000. At this time, a new lagoon for the Town of Hollandale was constructed to discharge into Black Bayou to replace the closed facility. The closed Hollandale facility, however, had a history of compliance problems that included violations in their permitted limit of BOD_5 and other parameters. The town also had problems with maintenance of the equipment and hiring of a certified operator needed to run the closed activated sludge facility. Discharge monitoring reports from 1999 and 2000 show that the reported BOD_5 of the effluent was as much as 3 times greater than their permit limit of 10 mg/L. Inspection reports show that equipment such as the grit chamber, aerator, and chlorination equipment was not working properly because the town did not have the resources to pay for the repairs. It is important to note that some of the data given in Section 2.1 were collected during the time that this facility was operating with these problems. The effluent from the Hollandale POTW could be responsible for some of the low DO measurements collected before 2000. Monitoring station 07288770 is located downstream of the location of the closed Hollandale facility. It is likely that the removal of this facility resulted in improvements in the water quality conditions at this location.

2.3 Assessment of Nonpoint Sources

Nonpoint sources of pollutants in Deer Creek have been observed for quite some time. A report published in 1972 by the Mississippi Game and Fish Commission (Parker and Robinson, 1972) noted that the creek had low dissolved oxygen problems in the fall season due to decaying vegetation. According to this report, pollution sources of concern were homes located on the creek banks, storm sewer drainage from the City of Leland, and runoff from cotton fields that border the creek. These nonpoint sources are still a concern today. Nonpoint loading of TBODu in a waterbody results from the transport of the pollutants into receiving waters by overland surface runoff and groundwater infiltration. Landuse activities within the drainage basin, such as agriculture, and urbanization contribute to nonpoint source loading. Other nonpoint pollution sources include atmospheric deposition and natural weathering of rocks and soil.

The 70,000-acre drainage area of Deer Creek contains many different landuse types, including urban, forest, cropland, pasture, water, and wetlands. The landuse information is based on data collected by the State of Mississippi's Automated Resource Information System (MARIS) 1997. This data set is based on Landsat Thematic Mapper digital images taken between 1992 and 1993. Agriculture is the dominant landuse within this watershed. The landuse distribution within the Deer Creek Watershed is shown in Table 12 and Figure 5. Land classified by MARIS as bottomland hardwood forest was grouped into the wetland category in Table 12.

Table 12. Landuse Distribution

Subwatershed	Urban	Forest	Cropland	Pasture	Barren	Wetland	Aquaculture	Water	Total
080302090DC	1,541	0	59,181	3,257	0	5,201	9	1,059	70,249
Total	2%	0%	84%	5%	0%	7%	0%	2%	100%

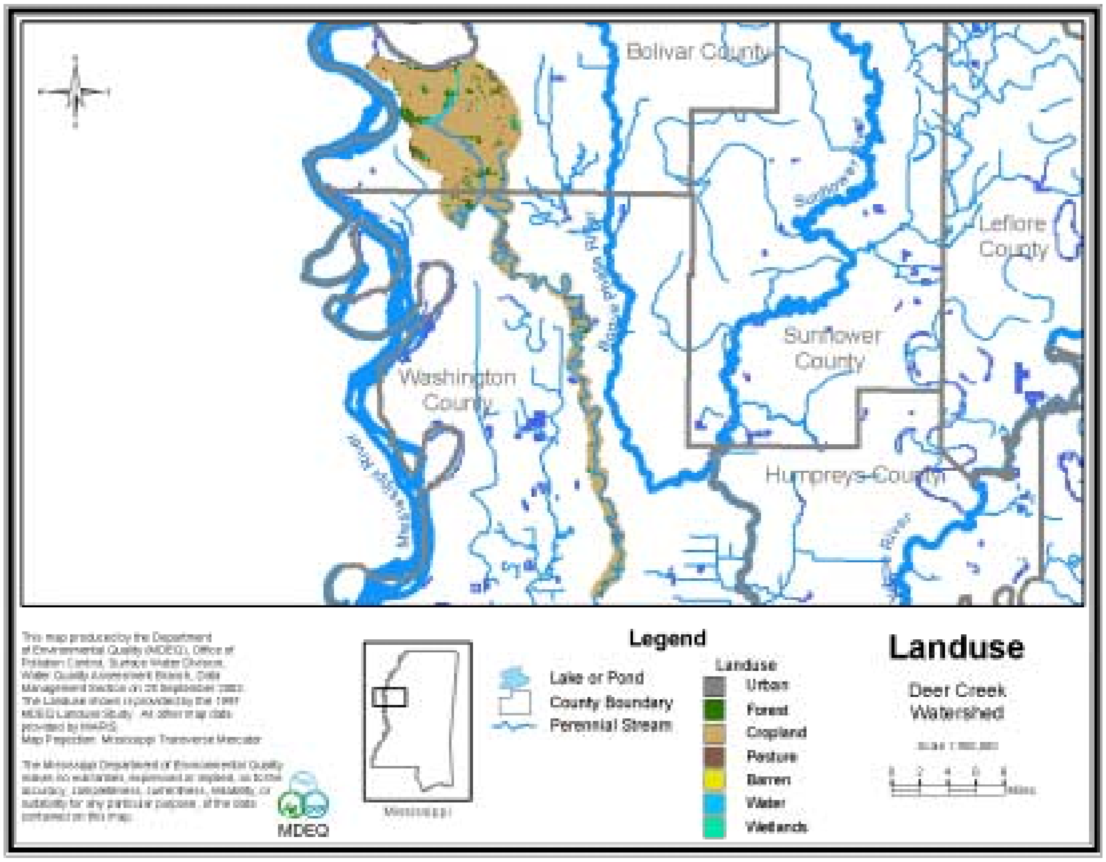


Figure 5. Landuse Distribution Map for Deer Creek Watershed

MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the instream water quality target and the source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions. In this section, the selection of the modeling tools, setup, and model application are discussed.

4.1 Modeling Framework Selection

A mathematical model, named AWFWUL1, for DO distribution in freshwater streams was used for developing the TMDL. The use of AWFWUL1 is promulgated in the *Wastewater Regulations for National Pollutant Discharge Elimination System (NPDES) Permits, Underground Injection Control (UIC) Permits, State Permits, Water Quality Based Effluent Limitations and Water Quality Certification* (MDEQ, 1994). This model has been approved by EPA and has been used extensively by MDEQ. A key reason for using the AWFWUL1 model in TMDL development is its ability to assess instream water quality conditions in response to point and nonpoint source loadings.

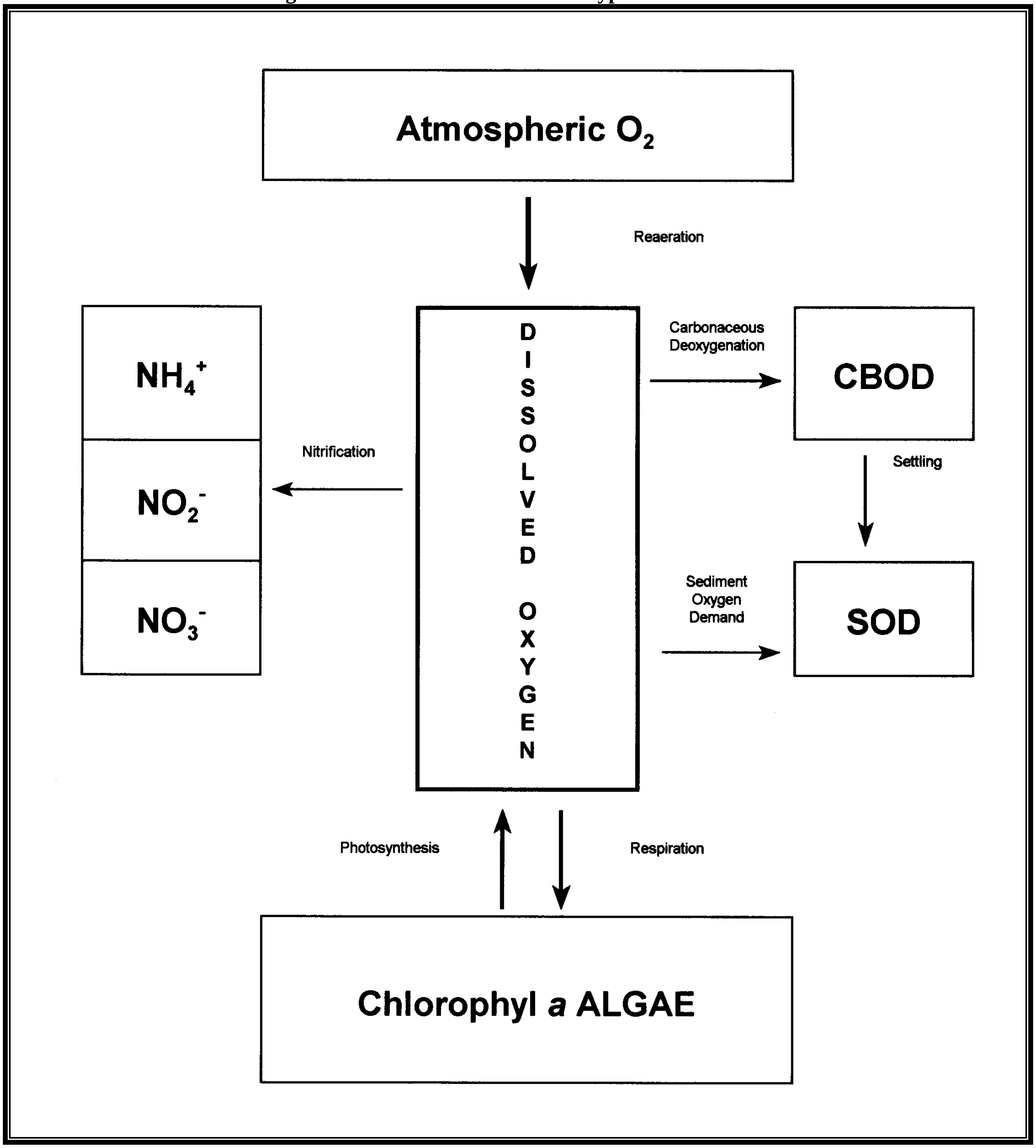
The model is a steady-state, daily average computer model that utilizes a modified Streeter-Phelps DO sag equation. Instream processes simulated by the model include CBODu decay, nitrification, reaeration, sediment oxygen demand, and respiration and photosynthesis of algae. Figure 6 shows how these processes are related in a typical DO model. Reaction rates for the instream processes are input by the user and corrected for temperature by the model. The model output includes water quality conditions in each computational element for DO, CBODu, and NH_3-N concentrations. The hydrological processes simulated by the model include stream velocity and flow from point sources and spatially distributed inputs.

The model was set up to calculate reaeration within each reach using the O'Conner-Dobbins formulation. This formula can be applied to streams with depths greater than 5 ft. The O'Conner-Dobbins formula calculates reaeration (Ka) within each reach according to Equation 2.

$$\mathbf{Ka = 12.9U^{0.5}/D^{1.5}} \qquad \textbf{(Equation 2)}$$

U is the reach velocity in ft/second and D is the stream depth in feet.

Figure 6. Instream Processes in a Typical DO Model



4.2 Model Setup

The Deer Creek TMDL model includes the 303(d) listed segment of Deer Creek, from Arcola to Percy, as well as all the drainage area upstream of the segment to Lake Bolivar. The modeled waterbody was divided into reaches for input into the AWFWUL1 model. Reach divisions were made at any major change in the hydrology of the waterbody, such as a significant change in slope or the confluence of a point source discharge. The watershed was modeled according to the diagram shown in Figure 7. Approximate locations of some of the monitoring stations are shown. The numbers on the figure represent river miles (RM). River miles are assigned to waterbodies, beginning with zero at the mouth. The slope of each reach was estimated from USGS quad maps and input into the model in units of feet/mile. Within each reach, the modeled segments were divided into computational elements of 0.1 mile. The hydrological and water quality characteristics are calculated and output by the model for each computational element.

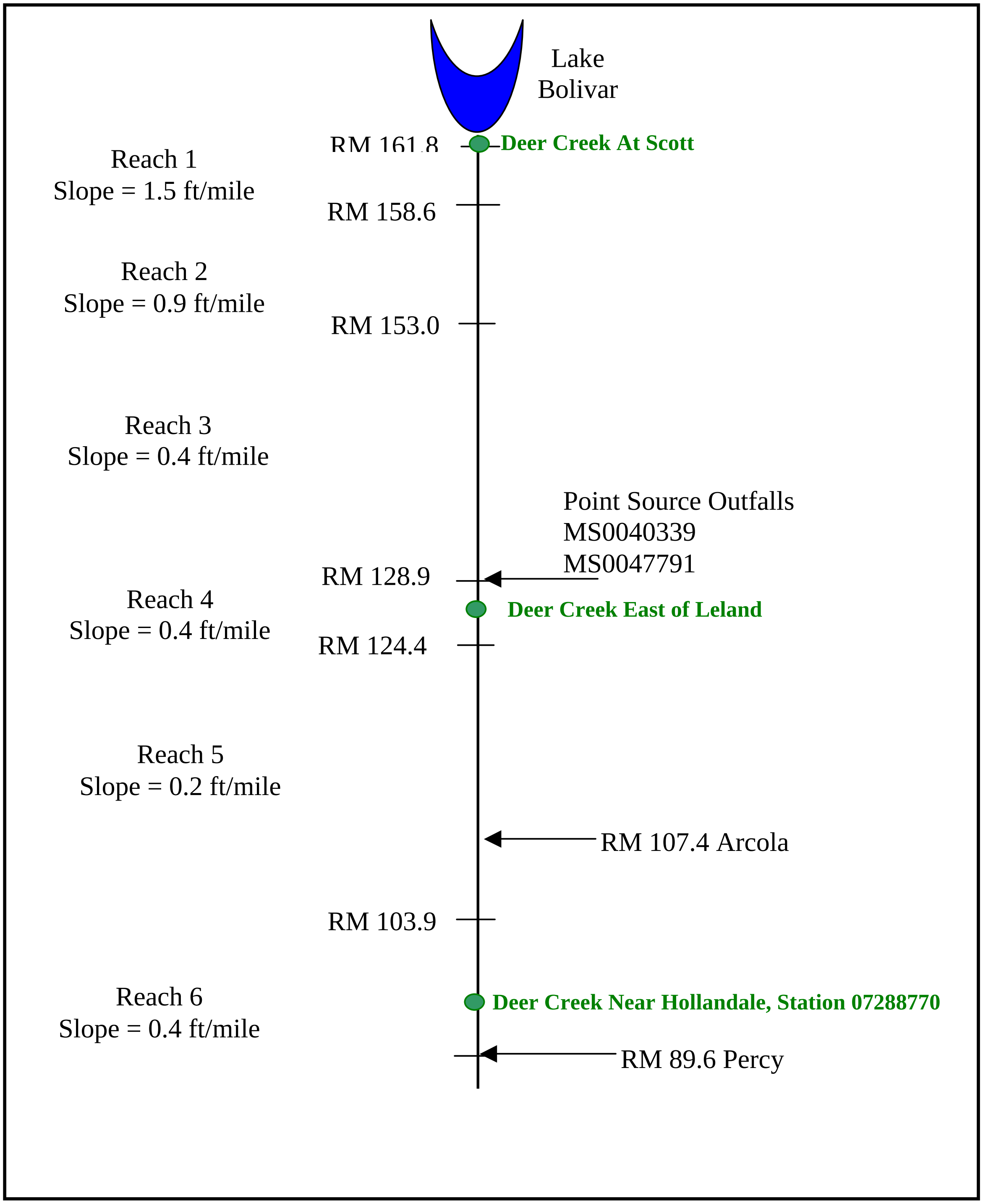


Figure 7. Deer Creek Model Setup (Note: Figure not to Scale)

The model was setup to simulate low-flow, high-temperature conditions, which was determined to be the critical condition for this TMDL. The temperature used in the model is 26°C. The headwater instream DO was assumed to be 85% of saturation at the stream temperature. The instream CBODu decay rate is dependent on temperature, according to Equation 3.

$$\mathbf{Kd_{(T)} = Kd_{(20°C)}(1.047)^{T-20}} \qquad \textbf{(Equation 3)}$$

Where Kd is the CBODu decay rate and T is the assumed instream temperature. The assumptions regarding the instream temperatures, background DO saturation, and CBODu decay rate are required by the *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). According to the requirements in this document, the SOD, photosynthesis, and respiration rates were set to zero due to lack of field measurements of these parameters.

4.3 Source Representation

Both point and nonpoint sources were represented in the model. The loads from NPDES permitted sources were added as direct inputs into the appropriate reach of the waterbody as a flow in cfs and a load of CBODu and ammonia nitrogen in lbs/day. Spatially distributed loads, which represent nonpoint sources of flow, CBODu, and ammonia nitrogen were distributed evenly into each computational element of Deer Creek and its tributaries. The estimated loads from discharges of wastewater from failing septic tanks were input as spatially distributed loads.

Organic material discharged to a stream from an NPDES permitted point source is typically quantified as 5-day biochemical oxygen demand (BOD_5). BOD_5 is a measure of the oxidation of carbonaceous and nitrogenous material over a 5-day incubation period. However, oxidation of nitrogenous material, called nitrification, usually does not take place within the 5-day period because the bacteria that are responsible for nitrification are normally not present in large numbers and have slow reproduction rates (Metcalf and Eddy, 1991). Thus, BOD_5 is generally considered equal to $CBOD_5$. Because permits for point source facilities are written in terms of BOD_5 while predictive models used for TMDL development are typically developed using CBODu, a ratio between the two terms is needed, Equation 4.

$$\mathbf{CBODu = CBOD_5 * Ratio} \qquad \textbf{(Equation 4)}$$

The CBODu to $CBOD_5$ ratios are given in *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). These values are recommended for use by MDEQ regulations when actual field data are not available. The value of the ratio depends on the treatment type. A ratio of 1.5:1 was used for both of the facilities included in the model.

In order to convert the ammonia nitrogen (NH_3-N) loads to an oxygen demand, a factor of 4.57 pounds of oxygen per pound of ammonia nitrogen (NH_3-N) oxidized to nitrate (NO_3) was used. Using this factor is a conservative modeling assumption because it assumes that all of the ammonia is converted to nitrate through nitrification, which is not necessarily accurate. The oxygen demand caused by nitrification of ammonia is equal to the NBODu load. The sum of

CBODu and NBODu is equal to the point source load of TBODu. The permitted loads of TBODu from each of the existing point sources are given in Table 13. Note that these loads are significantly larger than the actual discharge, as measured from the DMR data, Table 11.

Table 13. Point Source Loads as Input into the Model

Facility	Flow (cfs)	$CBOD_5$ (mg/l)	$CBOD_u$:$CBOD_5$ Ratio	CBODu (lbs/day)	NH_3-N (mg/l)	NBODu (lbs/day)	TBODu (lbs/day)
J. Whitten Delta Research	0.077	10	1.5	6.2	2	3.8	10.0
National Warm Water Aquaculture Center	0.89	10	1.5	72.0	2	43.9	115.8
Total				**78.2**		**47.7**	**125.8**

Direct measurements of nonpoint source loads of CBODu and NH_3-N were not available for the Deer Creek Watershed. The background contributions of CBODu and total ammonia as nitrogen (NH_3–N) were estimated based on *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). According to these regulations, the background concentrations used in modeling are CBODu = 2.0 mg/l and NH_3-N = 0.1 mg/l.

Due to lack of data, the nonpoint source flows in Deer Creek were also estimated. Low flow, critical conditions are typically estimated as the 7Q10 flow condition. However, due to extensive man-made modifications and groundwater pumping, which has caused a significant decrease in baseflows, 7Q10 flows are not available for streams in the Mississippi River alluvial plain. For the Deer Creek watershed, a low flow coefficient, rather than a 7Q10 flow, was used to represent low-flow conditions.

Because there is not a continuous record of flow available for Deer Creek, the low-flow coefficient was estimated based on data from a nearby waterbody in the Mississippi River alluvial plain. The waterbody located closest to the Deer Creek Watershed that has a long-term continuous record of flow is Bogue Phalia. The Bogue Phalia Watershed occupies an area of approximately 309,760 acres (484 square miles) and lies in parts of Washington, Bolivar, and Sunflower Counties. Bogue Phalia flows in a southern direction from its headwaters to its confluence with the Big Sunflower River near Darlove. USGS gage 07288650 is located on Bogue Phalia near Leland, MS. Though there are differences in the hydrological characteristics of these two waterbodies due to variations in watershed size, geology, and man-made modifications to the landscape, a flow coefficient (amount of flow per drainage area size) was extrapolated from Bogue Phalia to Deer Creek. Due to lack of flow data for the Deer Creek watershed, the accuracy of this method could not be determined.

Flow data for the USGS monitoring station on Bogue Phalia near Leland, which were available for 1986 through 2000, were used to develop a flow duration curve. The flow in Bogue Phalia at Leland that is equaled or exceeded 99% of the time (a lower flow would be expected only 1% of the time) was used to calculate the flow coefficient. For Bogue Phalia Creek, the 99^{th} percentile flow is 7.0 cfs. The contributing drainage area of Bogue Phalia, 484 square miles, was used to determine the low flow coefficient as shown below.

Low-Flow Coefficient (cfs/square mile) = 7.0 cfs/484 square miles = **0.014 cfs/square mile**

Then the critical condition low-flow for Deer Creek was estimated by multiplying by the contributing drainage area size of Deer Creek, 110 square miles.

Low-Flow in Deer Creek = 0.014 cfs/square mile * 110 square miles = **1.5 cfs**

After determining the drainage area of the Deer Creek Watershed, the low-flow coefficient (low-flow value in cfs/drainage area in square miles) was used to estimate the amount of water draining into each modeled reach of Deer Creek during low-flow conditions. The estimated flows were multiplied by the background concentrations of CBODu and NH_3-N to calculate the nonpoint source loads in the model. The nonpoint source loads make up a portion of the loads given in Table 14. It was assumed that the nonpoint source loads were evenly distributed within each reach.

Discharges of wastewater from failing septic systems and onsite wastewater treatment plants were also included as nonpoint sources of organic material and nutrients in Deer Creek. This type of discharge is suspected to be a cause of organic enrichment in Deer Creek because there are many homes located near the creek banks in rural areas. Actual measurements of the number of discharges from septic tanks and other sources have not been made in the Deer Creek watershed. However, the contribution from these sources has been estimated based on data from other areas. The percentage of failing septic tanks has been estimated based on interpretation of aerial photographs in another watershed in the Yazoo River Basin, Otoucalofa Creek. In this watershed, 3 percent of the septic systems were identified as having either a distinct moisture pattern with an identifiable plume from a visible field line or a visible suspicious moisture pattern. The observation of 3 percent was applied to the Deer Creek watershed to represent discharges of wastewater from septic tanks and onsite wastewater treatment systems. This estimate is not intended to represent discharge from the sewer lines to the wastewater treatment plants in the Cities of Leland, Arcola, and Hollandale. The NPDES permits are the control strategy for any failing sewage conveyance that is part of these facilities.

Loads of CBODu and NH_3-N from discharges of leaking wastewater were quantified using literature values. The $CBOD_5$ and NH_3-N concentrations of wastewater were assumed to be 220 mg/L and 15 mg/L (Metcalf and Eddy, 1991). The amount of wastewater produced per person each day was assumed to be 70 gal/day/person (Horsley and Whitten, 1996). Based on the watershed characterization system (WCS), it was estimated that 986 people in the watershed are served by septic systems. Based on these assumptions, the loads produced due to direct discharges from septic systems are included in Table 14. The loads were assumed to be evenly distributed along each reach. These loads were also assumed to be continuous sources of pollutants in the Deer Creek watershed, because pollutants leaking from septic systems could reach the creek during both wet and dry conditions.

It is important to note that the loads from direct discharges of wastewater are only an estimation of what may be occurring in the Deer Creek watershed. MDEQ does not currently have any data specific to Deer Creek that could be used to calculate these loads. These data could be obtained, however, if funding were available. Low-level infrared aerial photographs of the watershed were taken in February 2002, and are available for interpretation. Interpretation of these photographs could yield significant information about the watershed such as the locations of locations of septic tanks with visible moisture patterns, detailed landuse inventories, and riparian zone conditions. Because aerial photography interpretation is expensive, this activity has not yet occurred. Watershed-specific data could also be obtained from surveys of septic tanks and onsite wastewater treatment plants in the watershed.

Table 14. Nonpoint Source Loads as Input into the Model

Reach	Flow (cfs)	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
1	0.124	15.3	3.2	18.5
2	0.122	25.9	5.4	31.3
3	0.542	111.7	23.2	134.9
4	0.09	18.6	3.9	22.5
5	0.47	97.3	20.2	117.5
6	0.326	66.3	13.8	80.1
Total	**1.674**	**335.1**	**69.7**	**404.8**

4.4 Model Calibration

The model used to develop the Deer Creek Phase 1 TMDL was not calibrated due to lack of instream monitoring data collected during critical conditions. If additional data are collected in Deer Creek during the critical condition period, these data will be used to calibrate the model. If the calibrated model is significantly different than the Phase 1 model, a Phase 2 TMDL will be developed to reflect the updated model results.

4.5 Model Results

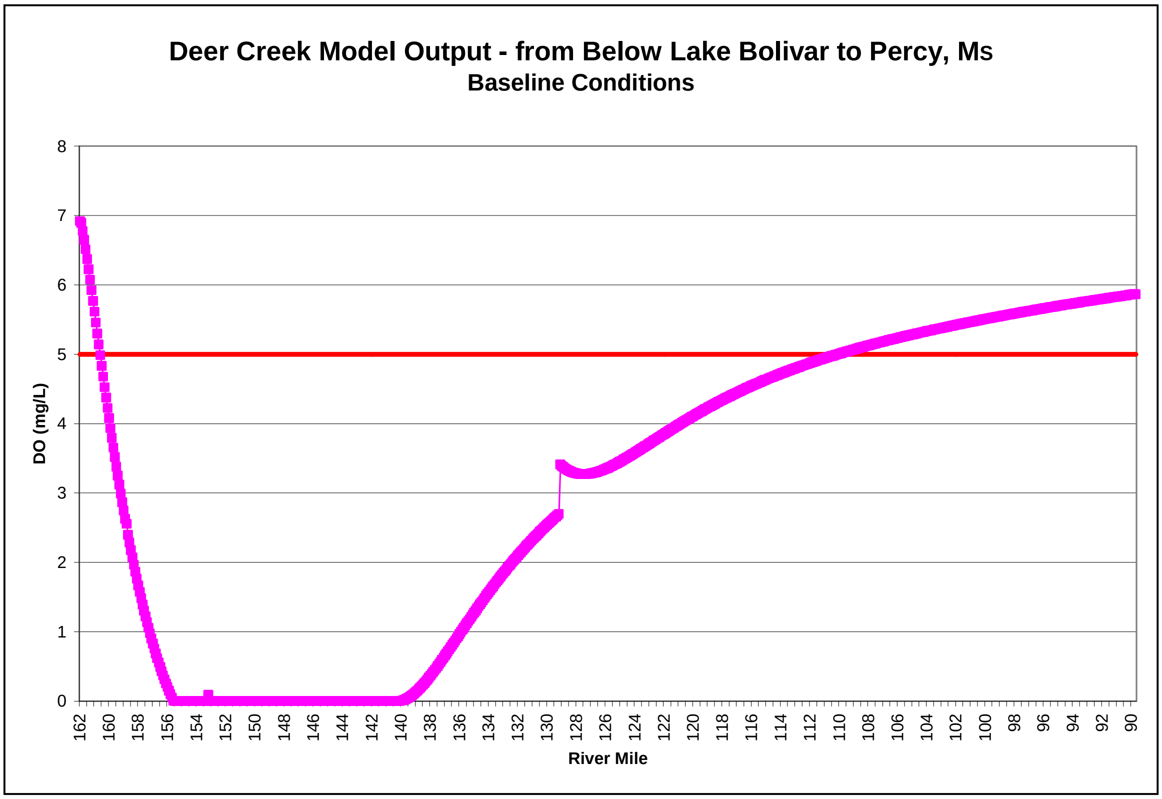
Once the model setup was complete, the model was used to predict water quality conditions in Deer Creek. The model was first run under baseline conditions. Under baseline conditions, the loads from NPDES permitted point sources were set at their existing loads as determined from the discharge monitoring reports, Table 13. Nonpoint source loads and loads from discharges from septic tanks were modeled according to the loads given in Table 14. Thus, baseline model runs reflect the current condition of Deer Creek without any reduction of the estimated TBODu loads. The model was then run using a trial-and-error process to determine the maximum TBODu loads which would not violate water quality standards for DO. These model runs are called maximum load scenarios.

4.5.1 Baseline Model Runs

The model results from the baseline model run is shown in Figure 8. The figure shows the modeled daily average DO in Deer Creek. The red line represents the DO standard of 5.0 mg/l. Figure 8 shows the daily average instream DO concentrations in Deer Creek under existing summer conditions, beginning with river mile 161.8 (just below Lake Bolivar) and ending with river mile 89.6 (at Percy). The modeled DO goes to zero in reach 3. The data show that the DO standard is violated in this reach as a result of the estimated loads from the discharges of wastewater. The model shows that the point sources, at river mile 128.9 have a small effect on the modeled DO level.

The inclusion of discharges of wastewater in the watershed shows that these sources of organic enrichment potentially have a much larger impact on the DO level in Deer Creek than NPDES permitted point sources. Sources from discharges of wastewater and other nonpoint sources, in fact, account for 76 percent of the TBODu load in the baseline condition model.

Figure 8. Baseline Model Output for Deer Creek



4.5.2 Maximum Load Scenarios

The graphs of baseline model output show that the predicted DO falls below the DO standard in Deer Creek during critical conditions. As a result, reductions from the baseline loads of TBODu are necessary in order to maintain a daily average DO of at least 5.0 mg/l.

The maximum load scenarios involved running the model using a trial-and-error process. The estimated loads from the discharges of wastewater were reduced first. The percentage of discharges was reduced from 3% to 0.5%. Reducing the estimated load from leaking septic tanks represented a major reduction in TBODu loading in Deer Creek. Also, the load from the permitted point sources was reduced by 35%. Reducing the point source load, however, represented a minor reduction in TBODu loading. The maximum load, that allowed the maintenance of water quality standards, was selected. The maximum load was used to develop the load and wasteload allocations proposed in this TMDL. Figure 9 shows the daily average instream DO concentrations in Deer Creek after application of the selected maximum load scenario for the critical condition. The lowest DO concentration in the creek, approximately 5.0 mg/l occurs near river mile 125. The TBODu loads included in the maximum load scenario are given in Table 15.

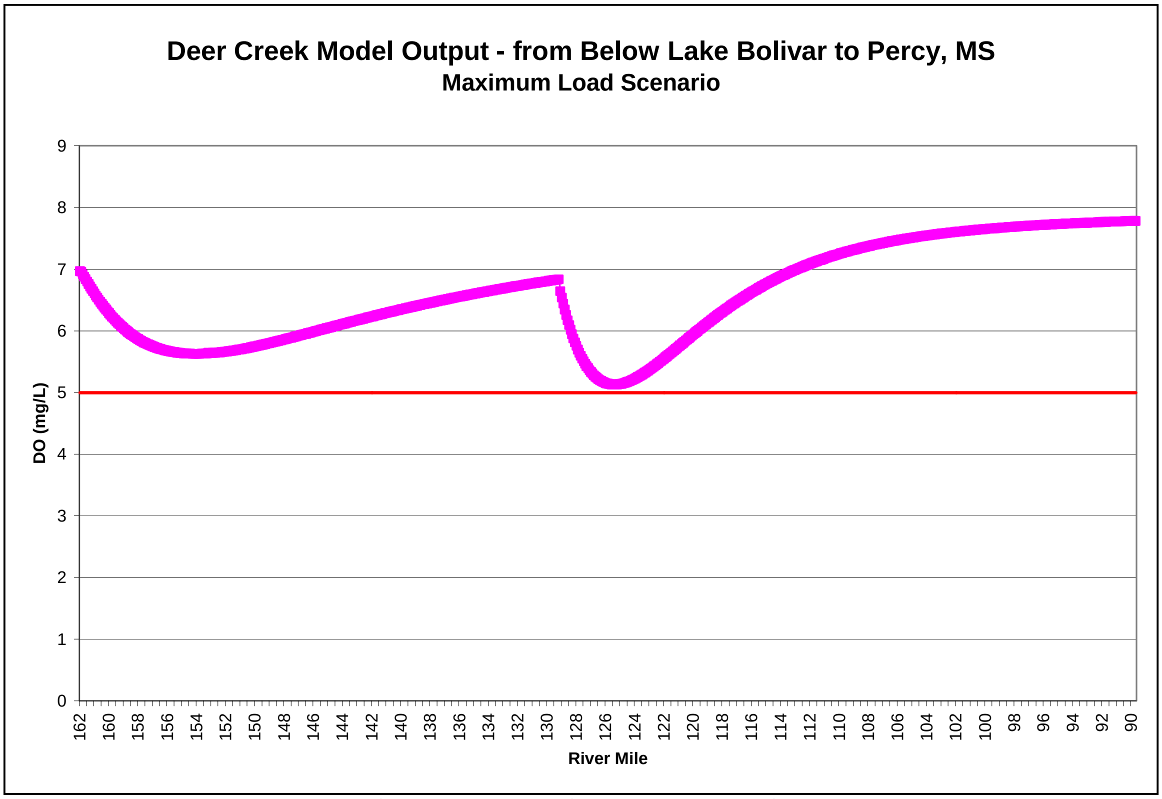


Figure 9. Model Output for Deer Creek after Application of Maximum Load Scenario

Table 15. Maximum Load Scenario, Critical Conditions

Source	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)	Percent Reduction
NPDES Permits	50.8	31.0	81.8	35%
Nonpoint Sources	69.3	14.7	84.0	79%
Total	**120.1**	**45.7**	**165.8**	**69%**

4.6 Evaluation of Ammonia Toxicity

Ammonia must not only be considered due to its effect on dissolved oxygen in the receiving water, but also its toxicity potential. Ammonia nitrogen concentrations can be evaluated using the criteria given in 1999 Update of Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014). The maximum allowable instream ammonia nitrogen (NH_3-N) concentration at a pH of 7.0 and stream temperature of 26°C is 2.82 mg/l. Based on the model results, this criteria was not exceeded in Deer Creek under the current NH_3-N loads.

ALLOCATION

The allocation for this TMDL involves a wasteload allocation for point sources and a load allocation for nonpoint sources necessary for attainment of water quality standards in segment MS403M6 and Drainage Area MS402E of Deer Creek.

5.1 Wasteload Allocation

Two NPDES Permitted facilities in the Deer Creek watershed are included in the wasteload allocation, Table 16. The model used to develop this TMDL has shown that the permitted point sources are a minor source of organic material in Deer Creek. The facilities are discharging only a fraction of the wasteload allocation at the present time (an average of 11.5 lbs/day TBODu based on DMRs for the past two years).

Table 16. Wasteload Allocation

Facility	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
J. Whitten Delta Research	4.0	2.5	6.5
National Warm Water Aquaculture Center	46.8	28.5	75.3
Total	**50.8**	**31.0**	**81.8**

5.2 Load Allocation

The spatially distributed nonpoint source loads and the estimated loads from discharges of wastewater are included in the load allocation. The TBODu concentrations of the nonpoint source loads were determined by using an assumed $CBOD_5$ concentration of 1.33 mg/l and an NH_3-N concentration of 0.1 mg/l. These concentrations should be assumed when reliable field data are not available, according to *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994).

The allocations for loads due to leaking septic tanks, along with the other nonpoint source loads, are shown in Table 17. The methods used to estimate these loads were described in Section 4.3. An overall 79 percent reduction from the estimated nonpoint source load is required in order to meet water quality standards for dissolved oxygen under low-flow critical conditions.

Table 17. Load Allocations

Reach	Flow (cfs)	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
1	0.115	3.6	0.8	4.3
2	0.114	5.3	1.2	6.5
3	0.492	22.9	4.9	27.8
4	0.082	3.8	0.8	4.7
5	0.429	20	4.2	24.2
6	0.292	13.6	2.9	16.5
Total	**1.524**	**69.2**	**14.8**	**84.0**

5.3. Seasonality

Seasonal variation may be addressed in the TMDL by using seasonal water quality standards or developing model runs to reflect seasonal variations in temperature and other parameters. Mississippi's water quality standards for dissolved oxygen, however, do not vary according to the seasons. The Deer Creek TMDL model was set up to simulate dissolved oxygen during the critical condition period, the low-flow, high-temperature period that typically occurs during the summer season. Since the critical condition represents the worst-case scenario, the TMDL developed for critical conditions is protective of the water body at all times. Thus, this TMDL will ensure attainment of water quality standards for each season.

5.4 Incorporation of a Margin of Safety

The margin of safety is another required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving waterbody. The two types of MOS development are to implicitly incorporate the MOS using conservative model assumptions or to explicitly specify a portion of the total TMDL as the MOS. The MOS selected for this model is implicit.

Conservative assumptions, which place a higher demand of DO on the waterbody than may actually be present, are considered part of the margin of safety. The assumption that all of the ammonia nitrogen present in the waterbody is oxidized to nitrate nitrogen, for example, is a conservative assumption. In addition, the TMDL is based on the critical condition of the waterbody, which is represented by the low flow. The low flow for Deer Creek is very small. Therefore, modeling the waterbody at this flow provides protection in the worst-case scenario.

5.5 Calculation of the TMDL

The TMDL was calculated based on Equation 5.

$$\textbf{TMDL = WLA + LA + MOS} \qquad \textbf{(Equation 5)}$$

Where WLA is the wasteload allocation, LA is the load allocation, and MOS is the margin of safety. All units are in lbs/day of TBODu. The TMDL for TBODu was calculated based on the maximum allowable loading of the pollutants in Deer Creek and its tributaries, according to the model. The TMDL calculations are shown in Table 18. As shown in the table, TBODu is the sum of CBODu and NBODu. The wasteload allocation incorporates the CBODu and NH_3-N contributions from identified NPDES Permitted facilities. The load allocation has been divided to two components. The nonpoint source component includes the spatially distributed TBODu and NH_3-N contributions from surface runoff and groundwater infiltration. The wastewater discharge component includes discharge of wastewater due to leaking septic systems and onsite wastewater treatment plants. The implicit margin of safety for this TMDL is derived from the conservative assumptions used in setting up the model.

Table 18. TMDL for TBODu, for Critical Conditions in Deer Creek

	LA (lbs/day)	WLA (lbs/day)	MOS	TMDL (lbs/day)
CBODu	69.3	50.8	Implicit	**120.1**
NBODu	14.7	31.0	Implicit	**44.7**
TBODu	**84.0**	**81.8**	**Implicit**	**165.8**

CONCLUSION

This Phase 1 TMDL will place restrictions on NPDES permitting activities in Deer Creek and its tributaries, such that the loading specified in this TMDL will not be exceeded. Steps need to be taken to ensure that the overall load of TBODu placed in this waterbody from point and nonpoint sources does not exceed the assimilative capacity of Deer Creek. The maximum load of TBODu, as determined by this TMDL, is 165.8 lbs/day.

6.1 Future Monitoring

MDEQ has adopted the Basin Approach to Water Quality Management, a plan that divides Mississippi's major drainage basins into five groups. During each year-long cycle, MDEQ's resources for water quality monitoring will be focused on one of the basin groups. During the next monitoring phase in the Yazoo Basin, Deer Creek may receive additional monitoring to identify any change in water quality. The additional monitoring may allow confirmation of the assumptions used in the model used for calculating the TMDL. If the additional data show that the assumptions used were not accurate, the model as well as the TMDL will be updated.

Other future data collection activities could include interpretation of the aerial photographs available for the Deer Creek watershed. Also, the watershed restoration effort currently underway in the Deer Creek watershed will also provide additional water quality data. This effort may also include implementation of restoration efforts that would reduce nonpoint pollutant sources in Deer Creek.

6.2 Public Participation

This TMDL will be published for a 30-day public notice. During this time, the public will be notified by publication in the statewide newspaper. The public will be given an opportunity to review the TMDL and submit comments. MDEQ also distributes all TMDLs at the beginning of the public notice to those members of the public who have requested to be included on a TMDL mailing list. TMDL mailing list members may request to receive the TMDL reports through either, email or the postal service. Anyone wishing to become a member of the TMDL mailing list should contact Linda Burrell at (601) 961-5062 or Linda_Burrell@deq.state.ms.us.

At the end of the 30-day period, MDEQ will determine the level of interest in the TMDL and make a decision on the necessity of holding a public hearing. If a public hearing is deemed appropriate, the public will be given a 30-day notice of the hearing to be held at a location near the watershed. That public hearing would be an official hearing of the Mississippi Commission on Environmental Quality, and would be transcribed.

All comments received during the public notice period and at any public hearings become a part of the record of this TMDL. All comments will be considered in the submission of this TMDL to EPA Region 4 for final approval.

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DEFINITIONS

5-Day Biochemical Oxygen Demand: Also called BOD_5, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over a period of 5 days.

Activated Sludge: A secondary wastewater treatment process that removes organic matter by mixing air and recycled sludge bacteria with sewage to promote decomposition

Aerated Lagoon: A relatively deep body of water contained in an earthen basin of controlled shape which is equipped with a mechanical source of oxygen and is designed for the purpose of treating wastewater.

Ammonia: Inorganic form of nitrogen (NH_3); product of hydrolysis of organic nitrogen and denitrification. Ammonia is preferentially used by phytoplankton over nitrate for uptake of inorganic nitrogen.

Ammonia Nitrogen: The measured ammonia concentration reported in terms of equivalent ammonia concentration; also called total ammonia as nitrogen (NH_3-N)

Ammonia Toxicity: Under specific conditions of temperature and pH, the unionized component of ammonia can be toxic to aquatic life. The unionized component of ammonia increases with pH and temperature.

Ambient Stations: A network of fixed monitoring stations established for systematic water quality sampling at regular intervals, and for uniform parametric coverage over a long-term period.

Assimilative Capacity: The capacity of a body of water or soil-plant system to receive wastewater effluents or sludge without violating the provisions of the State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters and Water Quality regulations.

Background: The condition of waters in the absence of man-induced alterations based on the best scientific information available to MDEQ. The establishment of natural background for an altered waterbody may be based upon a similar, unaltered or least impaired, waterbody or on historical pre-alteration data.

Biological Impairment: Condition in which at least one biological assemblages (e.g. , fish, macroinvertabrates, or algae) indicates less than full support with moderate to severe modification of biological community noted.

Carbonaceous Biochemical Oxygen Demand: Also called CBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous compounds under aerobic conditions over an extended time period.

Calibrated Model: A model in which reaction rates and inputs are significantly based on actual measurements using data from surveys on the receiving waterbody.

Conventional Lagoon: An un-aerated, relatively shallow body of water contained in an earthen basin of controlled shape and designed for the purpose of treating water.

Critical Condition: Hydrologic and atmospheric conditions in which the pollutants causing impairment of a waterbody have their greatest potential for adverse effects.

Daily Discharge: The "discharge of a pollutant" measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the "daily discharge" is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurement, the "daily average" is calculated as the average.

Designated Use: Use specified in water quality standards for each waterbody or segment regardless of actual attainment.

Discharge Monitoring Report: Report of effluent characteristics submitted by a NPDES Permitted facility.

Dissolved Oxygen: The amount of oxygen dissolved in water. It also refers to a measure of the amount of oxygen that is available for biochemical activity in a water body. The maximum concentration of dissolved oxygen in a waterbody depends on temperature, atmospheric pressure, and dissolved solids.

Dissolved Oxygen Deficit: The saturation dissolved oxygen concentration minus the actual dissolved oxygen concentration.

DO Sag: Longitudinal variation of dissolved oxygen representing the oxygen depletion and recovery following a waste load discharge into a receiving water.

Effluent Standards and Limitations: All State or Federal effluent standards and limitations on quantities, rates, and concentrations of chemical, physical, biological, and other constituents to which a waste or wastewater discharge may be subject under the Federal Act or the State law. This includes, but is not limited to, effluent limitations, standards of performance, toxic effluent standards and prohibitions, pretreatment standards, and schedules of compliance.

Effluent: Treated wastewater flowing out of the treatment facilities.

First Order Kinetics: Describes a reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.

Groundwater: Subsurface water in the zone of saturation. Groundwater infiltration describes the rate and amount of movement of water from a saturated formation.

Impaired Waterbody: Any waterbody that does not attain water quality standards due to an individual pollutant, multiple pollutants, pollution, or an unknown cause of impairment.

Land Surface Runoff: Water that flows into the receiving stream after application by rainfall or irrigation. It is a transport method for nonpoint source pollution from the land surface to the receiving stream.

Load Allocation (LA): The portion of a receiving water's loading capacity attributed to or assigned to nonpoint sources (NPS) or background sources of a pollutant

Loading: The total amount of pollutants entering a stream from one or multiple sources.

Mass Balance: An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving a defined area, the flux in must equal the flux out.

Nonpoint Source: Pollution that is in runoff from the land. Rainfall, snowmelt, and other water that does not evaporate become surface runoff and either drains into surface waters or soaks into the soil and finds its way into groundwater. This surface water may contain pollutants that come from land use activities such as agriculture; construction; silviculture; surface mining; disposal of wastewater; hydrologic modifications; and urban development.

Nitrification: The oxidation of ammonium salts to nitrites via *Nitrosomonas* bacteria and the further oxidation of nitrite to nitrate via *Nitrobacter* bacteria.

Nitrogenous Biochemical Oxygen Demand: Also called NBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading nitrogenous compounds under aerobic conditions over an extended time period.

NPDES Permit: An individual or general permit issued by the Mississippi Environmental Quality Permit Board pursuant to regulations adopted by the Mississippi Commission on Environmental Quality under Mississippi Code Annotated (as amended) §§ 49-17-17 and 49-17-29 for discharges into State waters.

Photosynthesis: The biochemical synthesis of carbohydrate based organic compounds from water and carbon dioxide using light energy in the presence of chlorophyll.

Point Source: Pollution loads discharged at a specific location from pipes, outfalls, and conveyance channels from either wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving stream.

Pollution: Contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the State, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance, or leak into any waters of the State, unless in compliance with a valid permit issued by the Permit Board.

Publicly Owned Treatment Works (POTW): A waste treatment facility owned and/or operated by a public body or a privately owned treatment works which accepts discharges which would otherwise be subject to Federal Pretreatment Requirements.

Reaeration: The net flux of oxygen occurring from the atmosphere to a body of water across the water surface.

Regression Coefficient: An expression of the functional relationship between two correlated variables that is often empirically determined from data, and is used to predict values of one variable when given values of the other variable.

Respiration: The biochemical process by means of which cellular fuels are oxidized with the aid of oxygen to permit the release of energy required to sustain life. During respiration, oxygen is consumed and carbon dioxide is released.

Sediment Oxygen Demand: The solids discharged to a receiving water are partly organics, which upon settling to the bottom decompose aerobically, removing oxygen from the surrounding water column.

Storm Runoff: Rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate than rainfall intensity, but instead flows into adjacent land or waterbodies or is routed into a drain or sewer system.

Streeter-Phelps DO Sag Equation: An equation which uses a mass balance approach to determine the DO concentration in a waterbody downstream of a point source discharge. The equation assumes that the stream flow is constant and that CBODu exertion is the only source of DO deficit while reaeration is the only sink of DO deficit.

Total Ultimate Biochemical Oxygen Demand: Also called TBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over an extended time period.

Total Kjeldahl Nitrogen: Also called TKN, organic nitrogen plus ammonia nitrogen.

Total Maximum Daily Load or TMDL: The calculated maximum permissible pollutant loading to a waterbody at which water quality standards can be maintained.

Waste: Sewage, industrial wastes, oil field wastes, and all other liquid, gaseous, solid, radioactive, or other substances which may pollute or tend to pollute any waters of the State.

Wasteload Allocation (WLA): The portion of a receiving water's loading capacity attributed to or assigned to point sources of a pollutant.

Water Quality Standards: The criteria and requirements set forth in *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. Water quality standards are standards composed of designated present and future most beneficial uses (classification of waters), the numerical and narrative criteria applied to the specific water uses or classification, and the Mississippi antidegradation policy.

Water Quality Criteria: Elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports the present and future most beneficial uses.

Waters of the State: All waters within the jurisdiction of this State, including all streams, lakes, ponds, wetlands, impounding reservoirs, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, situated wholly or partly within or bordering upon the State, and such coastal waters as are within the jurisdiction of the State, except lakes, ponds, or other surface waters which are wholly landlocked and privately owned, and which are not regulated under the Federal Clean Water Act (33 U.S.C.1251 et seq.).

Watershed: The area of land draining into a stream at a given location.

ABBREVIATIONS

7Q10 .... Seven-Day Average Low Stream Flow with a Ten-Year Occurrence Period

BASINS .... Better Assessment Science Integrating Point and Nonpoint Sources

BMP .... Best Management Practice

$CBOD_5$ .... 5-Day Carbonaceous Biochemical Oxygen Demand

CBODu .... Carbonaceous Ultimate Biochemical Oxygen Demand

CWA .... Clean Water Act

DMR .... Discharge Monitoring Report

DO .... Dissolved Oxygen

EPA .... Environmental Protection Agency

GIS .... Geographic Information System

HUC .... Hydrologic Unit Code

LA .... Load Allocation

MARIS .... Mississippi Automated Resource Information System

MDEQ .... Mississippi Department of Environmental Quality

MGD .... Million Gallons per Day

MOS .... Margin of Safety

NBODu .... Nitrogenous Ultimate Biochemical Oxygen Demand

NH_3 .... Total Ammonia

NH_3-N .... Total Ammonia as Nitrogen

NO_2+ NO_3 .... Nitrite Plus Nitrate

NPDES .... National Pollution Discharge Elimination System

RBA .... Rapid Biological Assessment

$TBOD_5$ .... 5-Day Total Biochemical Oxygen Demand

TBODu .... Total Ultimate Biochemical Oxygen Demand

TKN .... Total Kjeldahl Nitrogen

TN .... Total Nitrogen

TOC .... Total Organic Carbon

TP .... Total Phosphorous

USGS .... United States Geological Survey

WLA .... Waste Load Allocation

WWTP .... Wastewater Treatment Plant